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Effect of Hydro-cooling and Immersion in Salicylic Acid and Citric Acid on Quality and Storability of Guava Fruits (*Psidium guajava* L.)

Maha H. Abd El-Aziz
Handling Res. Dept., Horticulture Research Institute, ARC, Giza, Egypt.
Corresponding author: mhaabdelaziz1975@gmail.com

Abstract

Guavas is a perishable fruit has a very short postharvest life this generates the necessity to search for new technologies to extend fruit life. The objective of this study was to determine the beneficial effects of hydro-cooling, salicylic acid (SA) and citric acid (CA) as postharvest applications on guava (*Psidium guajava* L.) fruit quality during cold storage. Mature (yellowish-green) and freshly-harvested guava fruits were subjected to pre-cooling by using tap water at 2ºC for 10minutes (Hydro-cooling) and/or combined with SA and CA at 2 and 4mM and control (tape water) as dipping solutions, followed by storage at 10ºC and 90-95% relative humidity for 28 days. The results cleared that, Hydro-cooling companied with SA at 4mM postharvest treatment recorded the lowest fruit weight loss %, decay %, total sugars, SSC%, pectin methylesterase activity and retarded fruit color changes (Hunter "L", "b" and "a") as compared with others treatments till 28 days of cold storage. Furthermore, it maintained higher fruit firmness, acidity%, and vitamin C content during all storage (7, 14, 21 and 28 days) periods and extended fruit shelf life after storage as compared to control. The results suggested that, hydro-cooling technique combined with dipping in SA at 4mM postharvest treatment could be use for maintain guava fruit quality under cold storage at 10ºC and 90-95% RH. for 28days and prolong guava fruits shelf life.

Keywords: pre-cooling, Salicylic acid, Antioxidant, Fruit firmness and Guava fruits

Introduction

Guava (*Psidium guajava* L.) is one of the most important fruit trees grown in tropical and sub-tropical regions in about sixty countries of the world **(Saxena** and **Gandhi, 2014).** Guava fruits are delicious, rich in vitamin 'C', carotene, thiamine, antioxidants, pectin and minerals like calcium, phosphorus and iron. Guava fruits are consumed as fresh fruits and industrial as jam, jelly, nectar etc. (**Boora, 2012)**. In Egypt, guava trees are grow in total area reached about 37343 feddan and fruiting about 32674 feddan, yielding about 339520 tons **(Anonymous, 2017).** This fruit is highly perishable, sensitive to bruising and mechanical injuries and has a short shelf life due to its delicate skin which offers a little protection against stresses as the injury that may developer of diseases such as soft rot resulting wastes during storage and shortened the shelf life. Moreover, it is a climacteric fruit that show activity in the respiratory rates and high rate of ethylene production and consequently show fast ripening of fruits **(Jain *et al.*, 2003).** The sharing and exporting guava fruits could be enhanced throughout properly handled after harvest. So, the research for new technologies that could reduce the perishable, delay fruit ripening and enhances shelf life period after harvest is necessary **(Mitra *et al.*, 2012).** Several procedures were suggested for achieving these purpose as like pre-cooling, applications of antioxidants and natural growth regulators.

Pre-cooling technique is considered as a critical process to maintain fruits and vegetables **(Turk and Celik, 1994).** Pre-cooling was first introduced at 1904 **(Baladhiya and Doshi, 2016)** since then it has been given various definitions such as the removal of field heat from freshly harvested fruits in order to slow down metabolism and reduce deterioration prior to transport or storage also **(Rudnucki *et al.*, 1991).** It is pointed out that pre-cooling is likely the most important technique used in the maintenance of fruit freshness and marketable **(Baird, 1976).** The principal methods of pre-cooling for the perishable fruits includes room cooling, hydro-cooling, forced air cooling, package icing, vacuum cooling, with many variations within these techniques **(Wang, 2010).** Various pre-cooling methods were recommended. The choice of cooling method for different fruits and vegetables are influenced by different factors**.** Hydro-cooling was developed as an outgrowth of celery washing. It is a popular method because of simplicity and effectiveness. Hydro-cooling essentially is the utilization of cold water for lowering the temperature of fruits before further packing. There are various types of hydro-cooling techniques as lick conventional type, immersion type and batch type **(Baladhiya and Doshi, 2016).**

Cold storage technique is considered as one of the most effective methods to maintain fruit quality throughout reducing fruit respiration rate, ethylene production, ripening, senescence and decay incidence as well as reduces the enzymatic activities which retard fruit softening and extending shelf-life of perishables fruits **(Bron *et al.*, 2005)**. Moreover, **Jobling** (**2001**) stated that, for every 10ºC increase in fruit temperature the rate of respiration is roughly doubled or even trebled. For example an apple fruit held at 10ºC ripens and respires about 3 times as fast as that held at 0ºC. This increase in respiration has a direct impact on the shelf-life of fruits. In this respect, pre-cooling at 2ºC of guava fruits and storage at 10ºC showed a beneficial effect on visual appearance of fruits, delayed changes of color, reduced physiological weight loss, incidence of fruit browning and enhanced soluble solids content, also showed an acceptable visual appearance of the fruits up to 3.6 weeks compared to 1.6 and 1.3 weeks for the fruit stored at 5 and 15ºC, respectively **(Silip and Hajar, 2007).**

Antioxidants like ascorbic acid, citric acid, and sodium benzoate are commercially used in post-harvest sectors and food industries. These compounds reduce or delay the free radical formation and cell membrane deterioration which occurs by lipoxygenase and lipid peroxidation reactions, subsequently prevents different degenerative pathways that encourage ethylene production which may lead to accelerating the ripening **(Bousquet and Thimann, 1984)**. Citric acid is an antioxidant; its effects might due to their tissue activity **(Gordon, 1990).** So, it has been used to inhibit the activity of polyphenol oxidase this maintains browning activity at minimum levels **(Ahvenaien, 1996).** Citric acid effect on polyphenol oxidase activity thought decreasing tissue pH would decrease polyphenol oxidase activity **(Altunkaya and Gökmen, 2008).**

Salicylic acid, (2-hydroxybenzoic acid, $C_7H_6O_3$) is an endogenous plant growth regulator **(Asghari and Aghdam, 2010)** it plays an important role in metabolic and physiological responses in plants. Also, It is a natural and safe phenolic compound that effectively controlling post-harvest losses of horticultural crops. Moreover, it delays the ripening of fruits through inhibition of the ethylene biosynthesis and action **(Asghari and Aghdam, 2010).** Several researchers cleared the beneficial effects of salicylic acid on maintaining fruit quality and extending shelf life of numerous of fruits during storage as like kiwifruit **(Aghdam *et al.*, 2010),** strawberry **(Shafiee *et al.*, 2010)** peach **(Tareen *et al.*, 2012),** mango **(Netravati *et al.*, 2015)** and Murcott mandarin **(Ennab *et al.*, 2020).** Therefore, the present treatments was conducted to study the potential effects of hydro-cooling, citric acid and salicylic acid on maintaining the quality of guava fruits during cold storage and extending the shelf life at room temperature.

Materials and Methods

This investigation was conducted during 2017 and 2018 seasons on guava fruits (*Psidium guajava* L.) collected from 10 years old trees growing in a private orchard, El Nubaria region, El- Behaira Governorate, Egypt. The trees were planted at 5 × 5 m spacing in sandy soil under the drip irrigation system. The fruits were harvested at the maturity stage (yellowish-green) in the third week of August according to **Mercado-Silva *et al.* (1998)**. The selected fruits were uniform in shape, size and free of visible symptoms of decay. The harvested fruits were trans-located in plastic boxes, under ambient temperature (25±2ºC) immediately (within 2hours after harvest) to the laboratory of Postharvest and Handling, Fruits Department, Horticulture Research Institute, ARC, Giza, Egypt. The selected fruits were cleaned and 10 fruits were used for achieving the initial quality parameters at the picking date. The remaining fruit samples were divided into two main groups each one contains 300 fruits; the first one separated into five sub groups and then dipped in tap water at 25±2ºC (P_1) for 10 mints containing sodium hypochlorite at 0.2% as a surface sterilizer in addition to one of the five concentrations of salicylic acid, citric acid solutions at 2.0 and 4.0 mM and control. The second one was also divided into five sub groups and subjected to hydro-cooling treatment (P_2) through dipping in cold water at 2ºC for 10 mints with the same above-mentioned immersion treatments. So, this study included the following ten treatments of two factors (A & B).

The first factor (A) comprised of Hydro-cooling treatments as follows:

P_1: Control as dipping in tap water at room temperature (25 ± 2ºC) for 10 mints.

P_2: Hydro-cooling as dipping in cold water at 2ºC for 10 mints

The second factor (B) contained five concentrations of salicylic acid and citric acid as follows.

T_1 Control

T_2 dipping in salicylic acid at 2.0 mM

T_3 dipping in salicylic acid at 4.0 mM

T_4 dipping in citric acid at 2.0 mM

T_5 dipping in citric acid at 4.0 mM

Salicylic acid (SA) was prepared by dissolving SA powder in 5ml ethanol alcohol and then raised to 10 liters of tap water. However citric acid was dissolved directly in tap water.

All fruits were air-dried to remove the surface moisture and then packed in carton boxes (15 fruits/ carton). All the boxes were stored in a cold room at 10°C and 90-95 relative humidity (RH) for 28days. A sample of each treatment (carton box) was taken out every 7days up to the end of the storage period to evaluate guava fruit quality during storage. The following parameters were measured:

Fruit physical characteristics

Weight loss%:

Fruit weight loss percentage was calculated depending on the initial weight of fruits as the following equation:

$$\text{Weight loss\%} = \frac{W0 - W1}{W0} X100$$

Where: W0 = fruit weight at harvest time and W1= fruit weight after each storage period (7, 14, 21 and 28 days)

Decay percentage:

Fruit decay percent was calculated by recording the number of decayed fruits every seven days of cold storage and calculated as percentages of the initial number of stored fruits in help with the following equation:

$$\text{Decay\%} = \frac{N1}{N0} X100$$

Where: N0= initial number of stored fruit and N1 = number of decayed fruits at the specified storage period (7, 14, 21 and 28 days).

At the picking date and during the storage period, the following parameters were conducted.

Fruit Firmness:

Fruit firmness was measured at two equatorial sites of three guava fruits per replicate by using a hand dynamometer apparatus model FDP1000 with an 8mm plunger tip **(Watkins and Harman, 1981).** Fruit firmness value was expressed as kg/cm^2.

Fruit color changes

The skin color of guava fruits was determined calorimetrically by using Hunter Color apparatus (Colorflex XE, Hunter Lab). The color values were expressed as Hunter scale (L, a, and b). The readings were recorded for each sample at three different points on the equatorial region of fruit. Data of Hunter 'L' indicates lightness of the fruit (0 for black and 100 for white) color, 'a' value represents greenness and redness (- 80 for green and 80 for red). Similarly, 'b' represents yellow and blue colors (80 for yellow and -80 for blue) and 0 is considered neutral **(McGuire, 1992).**

Fruit chemical characteristics:

Vitamin C (ascorbic acid)

Vitamin C was estimated according to **Ranganna (1997).** Fruit samples (50g) were mixed with 50ml oxalic acid solution (3%) by using a blander. the extracts were filtrated and then titrated against 2, 6-dichlorophenol-indophenol solution. The results were expressed as mg ascorbic acid per100g of fruit.

Pectin methylesterase activity (PME)

The activity of Pectin methylesterase enzyme was determined as described by **Anthon and Barrett (2006)** using 50g of fruits sample. The results were calculated as µmol /100g of fresh weight per hour (unit/ h).

Soluble solids content (SSC %), titratable acidity % and SSC/acid ratio

Fruit juice SSC% was measured with the help of a hand refractometer and expressed in °Brix. Fruit acidity percentages were assayed using 10ml of fruit juice titrated against 0.1 N NaOH in the presence of an indicator (phenolphthalein) as described by **A.O.A.C. (2000).** The data were expressed as citric acid percentages. SSC/acid ratio was calculated depending on SSC% and titratable acidity recorded data.

Shelf life (days)

After 28 days of cold storage, guava fruit samples from each treatment (five fruits) were placed at ambient conditions (25±2°C and 60-65% RH) as shelf life experiment. It was terminated when about 50% of fruits became unacceptable to marketing (lost the shining - very soft - sharking - decayed). The number of days was recorded and considered as shelf-life period for fruits.

Statistical analysis

The experiment treatments were arranged in randomized complete blok design with two factors, Hydro-cooling (A) and postharvest treatments (B). The collected data were analyzed as a factorial experiment using analysis of variance (ANOVA) according to **Snedecor and Cochran (1980)** with the help of the MSTAT-C statistical package software (M-STAT, 1993). The differences among means were compared by using Duncan's multiple range tests (DMRT) at 0.05 levels according to **Duncan (1955).** Also, Person correlation coefficient (r) was calculated for some chosen fruit characters.

Results and Discussion

Weight loss%

The results illustrated as Figures 1a , b showed that, hydro-cooling by using tap water at 2°C for 10min treatment was effective in reducing physiological weight loss percent of guava fruits during cold storage at 10°C and 90- 95 relative humidity (RH) till 28 days as compared to dipping in tap water at room temperature (25 ± 2°C). Moreover, postharvest application of citric acid at 2 and 4mM (T_2 and T_3) as well as salicylic acid at 2 and 4mM (T_4 and T_5) as dipping treatments for 10mintes regardless Hydro-cooling treatment showed a positive effect on physiological weight loss percentages of fruits throughout all storage periods (from 7 to 28 days of cold storage) as compared to control. In this respect, the application of SA at 4mM (T_5) treatment showed the lowest percentage of fruit losses until the end of storage time (28 days). This trend was true during both seasons of the study. Concerning the interaction, data of Table 1 clear that, the loss in fruit weight percent was increased with the incidence of storage time. Hydro-cooling combined with dipping treatments were effective in reducing the percent of physiological weight loss of guava fruits as compared with control. In this respect, guava fruits subjected to Hydro-cooling combined with salicylic acid at both 2and 4mM (P_2T_4 and P_2T_5) treatments showed the significant lowest weight loss percent in both seasons.

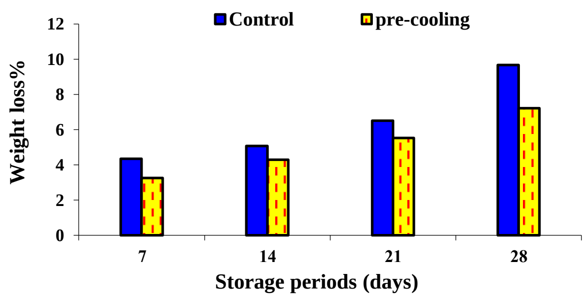
Fruit decay %

The data illustrated in Figures 2 a, b show that, hydro-cooling (tap water at 2ºC for 10m) treatment reduced decay percentages of guava fruits till 28 days of cold storage (10ºC and 90- 95RH) in both seasons as compared with control (dipping in tap water at room temperature). At the same time, postharvest application of citric acid (T_2 and T_3) and salicylic acid (T_4 and T_5) as dipping treatments for 10m, regardless hydro-cooling treatment reduced decay percentages of fruits throughout all storage periods as compared to control (T_1). In this respect, the application of citric acid (CA) as well as salicylic acid (SA) at all concentrations, did not show any decay percentages until 14 days of cold storage. Moreover, the application of SA at 2 and 4mM (T_4 and T_5) did not show any decay percent after 21 days of cold storage in both seasons. Whoever, the application of SA at 4mM (T_5) recorded the lowest fruit decay percentages. In this respect, the application of citric acid (CA) as well as salicylic acid (SA) at all concentrations, did not show any decay percentages until 14 days of cold storage. Moreover, the application of SA at 2 and 4mM (T_4 and T_5) did not show any decay percent after 21 days of cold storage in both seasons. Whoever, the application of SA at 4mM (T_5) recorded the lowest fruit decay percentages at the end of storage (28 days) during both seasons. Also, all post-harvest applications (T_2, T_3, T_4, and T_5) alone or in companied with hydro-cooling treatment did not record any fruit decay after 14 days of cold storage (Table 2). Moreover, the application of SA (T_4 and T_5) alone as well as T_3, T_4 and T_5 in combined with hydro-cooling also did not show any fruit decay till 21days of storage. This trend was cleared during both seasons. Whoever, with the incidence of storage time, T_3, T_4 and T_5 applications combined with hydro-cooling recorded the lowest percentages of fruit decay at 28 days of storage in the first season. By the second one, the interaction among hydro-cooling and both T_4 and T_5 dipping treatments prevent guava fruits against decays, since it did not record any decayed fruits till 28days of cold storage. However, control fruits recorded the highest percentage of decay in all storage periods and seasons.

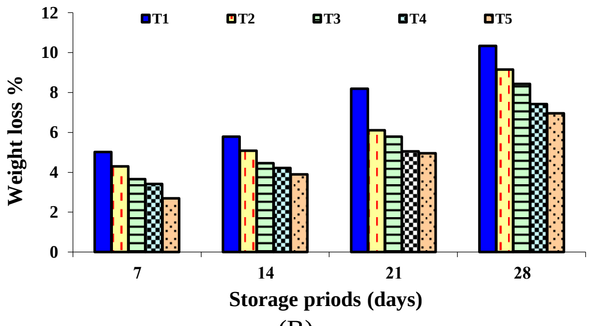
Fruit firmness

Data presented in Table 3 show that, hydro-cooling treatment was effective in maintaining guava fruit firmness under cold storage since it recorded the highest values throughout all storage periods as compared to control during the two seasons. Regarding dipping treatments, data of the same Table (3) clear that guava fruits dipped in Salicylic acid (SA) solutions (T_4 and T_5) showed the highest values of firmness as compared with the others in the first season. By the second season, the application of SA at 2mM (T_4) recorded the significant highest values as compared with others. However, the guava fruit of control recorded the lowest values during both seasons.

Concerning the interaction between hydro-cooling and dipping treatments, it could be noticed that, guava fruits that subjected to SA at 2 and 4mM (T_4 and T_5) treatments regardless hydro-cooling showed the highest values of firmness after 7 days of storage, but with the incidence of storage time, application of both CA and SA in combination with hydro-cooling (P_2T_2, P_2T_3, P_2T_4, and P_2T_5) treatments were more effective to maintaining fruit firmness till 28days of cold storage in the first season. However, the interaction between hydro-cooling and SA (P_2T_5) treatment reached the highest significant values of firmness during all storage periods (from 7 to 28 days) in the second season.



(A)



(B)

Figure 1. Effect of hydro-cooling (A), citric acid and salicylic acid (B) concentrations on average of weight loss % of both seasons of guava fruits during cold storage during 2017 and 2018 seasons.

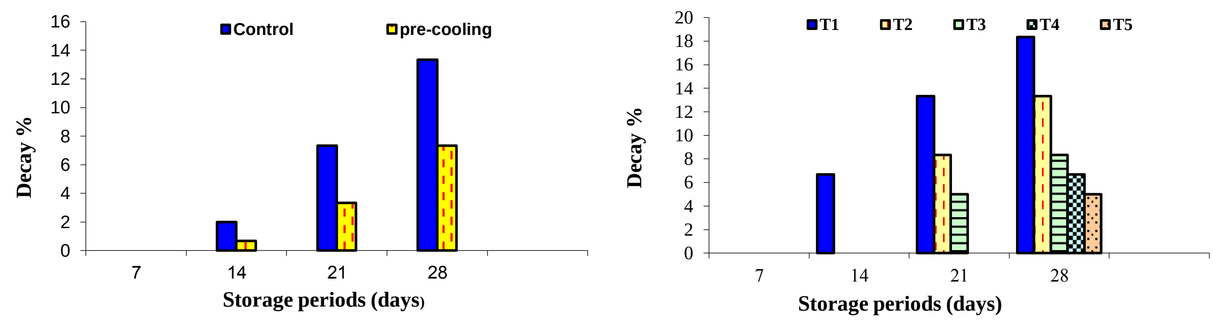
T_1=*Control,* ***T_2***= *Citric acid at 2mM,* ***T_3***= *Citric acid at 4mM,* ***T_4***= *Salicylic acid at 2mM and* ***T_5***= *Salicylic acid at 4mM.*

Table 1. Effect of hydro-cooling and immersion in citric acid and salicylic acid on physiological weight loss % of guava fruits during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Interaction										
P_1T_1	5.97^{a}	6.86^{a}	9.14^{a}	12.26^{a}	**8.56^{A}**	4.83^{a}	5.72^{a}	8.42^{a}	10.22^{a}	**7.30^{A}**
P_1T_2	4.95^{b}	5.62^{b}	6.03^{c}	10.48^{b}	**6.77^{C}**	4.33^{b}	5.13^{b}	7.11^{c}	9.92^{b}	**6.62^{B}**
P_1T_3	4.29^{c}	4.94^{cd}	6.15^{c}	10.62^{b}	**6.50^{C}**	4.02^{bc}	4.66^{c}	6.62^{d}	9.08^{c}	**6.10^{C}**
P_1T_4	4.17^{c}	4.70^{d}	5.67^{d}	9.28^{d}	**5.96^{D}**	4.25^{b}	4.69^{c}	5.47^{e}	8.55^{d}	**5.74^{D}**
P_1T_5	3.31^{d}	4.30^{e}	5.29^{e}	8.27^{e}	**5.29^{E}**	3.44^{de}	4.22^{d}	5.13^{f}	8.11^{e}	**5.23^{E}**
P_2T_1	5.16^{b}	5.65^{b}	7.74^{b}	10.11^{c}	**7.17^{B}**	4.08^{bc}	4.87^{bc}	7.41^{b}	8.71^{d}	**6.27^{C}**
P_2T_2	4.15^{c}	5.28^{bc}	5.72^{d}	8.11^{ef}	**5.82^{D}**	3.75^{cd}	4.31^{d}	5.57^{e}	8.07^{e}	**5.43^{E}**
P_2T_3	3.10^{de}	4.18^{e}	5.50^{de}	7.86^{f}	**5.16^{E}**	3.21^{e}	4.06^{d}	4.87^{f}	6.15^{f}	**4.57^{F}**
P_2T_4	2.68^{e}	3.78^{f}	4.89^{f}	6.52^{g}	**4.47^{F}**	2.55^{f}	3.68^{e}	4.15^{g}	5.32^{g}	**3.93^{G}**
P_2T_5	1.83^{f}	3.61^{f}	5.05^{f}	6.29^{g}	**4.25^{F}**	2.22^{f}	3.43^{e}	4.17^{g}	5.12^{g}	**3.74^{G}**
Mean	**3.96^{D}**	**4.89^{C}**	**6.14^{B}**	**8.98^{A}**		**3.67^{D}**	**4.48^{C}**	**5.89^{B}**	**7.93^{A}**	

Means followed by the same letters in each column, except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

P₁=*Dipping in tap water at room temperature at 25 ± 2ºC for 10mints,* ***P₂***= *(Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints ,* ***T₁***=*Control,* ***T₂***= *Citric acid at 2mM,* ***T₃***= *Citric acid at 4mM,* ***T₄***= *Salicylic acid at 2mM and* ***T₅***= *Salicylic acid at 4mM.*



(A) (B)

Figure 2. Effect of hydro-cooling (A) citric acid and salicylic acid (B) on average decay% of both seasons of guava fruits during cold storage at 10^{0}C and 90-95 RH during 2017 and 2018 seasons
T₁=*Control,* ***T₂***= *Citric acid at 2mM,* ***T₃***= *Citric acid at 4mM,* ***T₄***= *Salicylic acid at 2mM and* ***T₅***= *Salicylic acid at 4mM.*

Table 2. Effect of hydro-cooling and immersion in citric acid and salicylic acid on fruit decay % of guava fruits during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Interaction										
P_1T_1	0.00^{a}	13.33^{a}	20.00^{a}	26.67^{a}	**15.00^{A}**	0.00^{a}	6.67^{a}	13.33^{a}	20.00^{a}	**10.00^{A}**
P_1T_2	0.00^{a}	0.00^{c}	13.33^{b}	20.00^{b}	**8.33^{B}**	0.00^{a}	0.00^{b}	6.67^{b}	13.33^{b}	**5.00^{B}**
P_1T_3	0.00^{a}	0.00^{c}	13.33^{b}	13.33^{c}	**6.67^{C}**	0.00^{a}	0.00^{b}	6.67^{b}	6.67^{c}	**3.34^{C}**
P_1T_4	0.00^{a}	0.00^{c}	0.00^{d}	13.33^{c}	**3.33^{E}**	0.00^{a}	0.00^{b}	0.00^{c}	6.67^{c}	**1.67^{D}**
P_1T_5	0.00^{a}	0.00^{c}	0.00^{d}	6.67^{d}	**1.67^{F}**	0.00^{a}	0.00^{b}	0.00^{c}	6.67^{c}	**1.67^{D}**
P_2T_1	0.00^{a}	6.67^{b}	13.33^{b}	13.33^{c}	**8.33^{B}**	0.00^{a}	0.00^{b}	6.67^{b}	13.33^{b}	**5.00^{B}**
P_2T_2	0.00^{a}	0.00^{c}	6.67^{c}	13.33^{c}	**5.00^{D}**	0.00^{a}	0.00^{b}	6.67^{b}	6.67^{c}	**3.34^{C}**
P_2T_3	0.00^{a}	0.00^{c}	0.00^{d}	6.67^{d}	**1.67^{F}**	0.00^{a}	0.00^{b}	0.00^{c}	6.67^{c}	**1.67^{D}**
P_2T_4	0.00^{a}	0.00^{c}	0.00^{d}	6.67^{d}	**1.67^{F}**	0.00^{a}	0.00^{b}	0.00^{c}	0.00^{d}	**0.00^{E}**
P_2T_5	0.00^{a}	0.00^{c}	0.00^{d}	6.67^{d}	**1.67^{F}**	0.00^{a}	0.00^{b}	0.00^{c}	0.00^{d}	**0.00^{E}**
Mean	**0.00^{D}**	**2.00^{C}**	**6.67^{B}**	**12.67^{A}**		**0.00^{D}**	**0.67^{C}**	**4.00^{B}**	**8.00^{A}**	

Means followed by the same letters in each column, except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

P₁=*Dipping in tap water at room temperature at 25 ± 2ºC for 10mints,* ***P₂***= *(Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints ,* ***T₁***=*Control,* ***T₂***= *Citric acid at 2mM,* ***T₃***= *Citric acid at 4mM,* ***T₄***= *Salicylic acid at 2mM and* ***T₅***= *Salicylic acid at 4mM.*

Table 3. Effect of hydro-cooling, and immersion in citric acid and salicylic acid on fruit firmness (Kg/cm^2) of guava fruits during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017					2018				
	Cold storage periods (days)					Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Pre-cooling treat.										
P_1:Control	3.98^{b}	3.58^{b}	3.17^{b}	2.81^{b}	$\mathbf{3.39^{B}}$	3.72^{b}	3.36^{b}	2.95^{b}	2.59^{b}	$\mathbf{3.15^{B}}$
P_2:Hydro-cooling	4.22^{a}	3.93^{a}	3.68^{a}	3.35^{a}	$\mathbf{3.80^{A}}$	4.38^{a}	4.01^{a}	3.71^{a}	3.37^{a}	$\mathbf{3.87^{A}}$
Dipping treat.										
T_1:Control	3.82^{c}	3.19^{c}	2.61^{c}	2.25^{c}	$\mathbf{2.97^{C}}$	3.58^{d}	3.19^{c}	2.66^{d}	2.27^{c}	$\mathbf{2.93^{D}}$
T_2:CA 2 mM	4.03^{ab}	3.73^{b}	3.42^{b}	2.95^{b}	$\mathbf{3.54^{B}}$	3.81^{cd}	3.50^{bc}	3.14^{c}	2.81^{b}	$\mathbf{3.31^{C}}$
T_3:CA 4mM	4.03^{ab}	3.75^{b}	3.47^{b}	3.20^{ab}	$\mathbf{3.61^{AB}}$	4.03^{bc}	3.70^{b}	3.38^{bc}	2.95^{b}	$\mathbf{3.52^{BC}}$
T_4:SA 2 mM	4.30^{a}	4.02^{a}	3.84^{a}	3.48^{a}	$\mathbf{3.91^{A}}$	4.25^{ab}	3.86^{ab}	3.56^{ab}	3.32^{a}	$\mathbf{3.75^{B}}$
T_5:SA 4mM	4.32^{a}	4.09^{a}	3.82^{a}	3.52^{a}	$\mathbf{3.94^{A}}$	4.60^{a}	4.20^{a}	3.90^{a}	3.54^{a}	$\mathbf{4.06^{A}}$
Interaction										
P_1T_1	3.53^{d}	2.94^{c}	2.12^{c}	1.86^{d}	$\mathbf{2.61^{C}}$	3.31^{g}	2.73^{f}	2.01^{g}	1.72^{h}	$\mathbf{2.44^{G}}$
P_1T_2	3.83^{c}	3.40^{b}	3.05^{b}	2.50^{c}	$\mathbf{3.20^{B}}$	3.48^{fg}	3.21^{e}	2.85^{f}	2.51^{g}	$\mathbf{3.01^{F}}$
P_1T_3	3.90^{c}	3.53^{b}	3.18^{b}	2.90^{b}	$\mathbf{3.38^{B}}$	3.63^{f}	3.32^{e}	3.00^{f}	2.47^{g}	$\mathbf{3.11^{F}}$
P_1T_4	4.31^{a}	3.97^{a}	3.77^{a}	3.29^{a}	$\mathbf{3.84^{A}}$	3.85^{e}	3.52^{d}	3.21^{e}	3.01^{ef}	$\mathbf{3.40^{E}}$
P_1T_5	4.34^{a}	4.05^{a}	3.75^{a}	3.49^{a}	$\mathbf{3.91^{A}}$	4.34^{c}	4.01^{b}	3.66^{c}	3.22^{d}	$\mathbf{3.81^{C}}$
P_2T_1	4.10^{b}	3.44^{b}	3.09^{b}	2.64^{bc}	$\mathbf{3.32^{B}}$	3.85^{e}	3.64^{cd}	3.31^{de}	2.82^{f}	$\mathbf{3.41^{E}}$
P_2T_2	4.23^{ab}	4.05^{a}	3.79^{a}	3.40^{a}	$\mathbf{3.87^{A}}$	4.13^{d}	3.78^{c}	3.42^{d}	3.11^{de}	$\mathbf{3.61^{D}}$
P_2T_3	4.16^{ab}	3.97^{a}	3.75^{a}	3.49^{a}	$\mathbf{3.84^{A}}$	4.42^{c}	4.07^{b}	3.76^{bc}	3.42^{c}	$\mathbf{3.92^{BC}}$
P_2T_4	4.29^{a}	4.07^{a}	3.90^{a}	3.66^{a}	$\mathbf{3.98^{A}}$	4.65^{b}	4.19^{ab}	3.91^{b}	3.63^{b}	$\mathbf{4.10^{B}}$
P_2T_5	4.31^{a}	4.12^{a}	3.88^{a}	3.55^{a}	$\mathbf{3.97^{A}}$	4.86^{a}	4.38^{a}	4.14^{a}	3.85^{a}	$\mathbf{4.31^{A}}$
Mean	$\mathbf{4.10^{A}}$	$\mathbf{3.76^{AB}}$	$\mathbf{3.43^{C}}$	$\mathbf{3.08^{D}}$		$\mathbf{4.05^{A}}$	$\mathbf{3.69^{AB}}$	$\mathbf{3.33^{B}}$	$\mathbf{2.98^{C}}$	
	Initial value= 4.47					Initial value= 5.18				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

***P_1**=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, **P_2**= (Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints , **T_1**=Control, **T_2**= Citric acid at 2mM, **T_3**= Citric acid at 4mM, **T_4**= Salicylic acid at 2mM and **T_5**= Salicylic acid at 4mM.*

Pectin methylesterase activity (PME)

Data presented in Table 4 show that, the activity of PME was severely affected by the use of hydro-cooling (P_2) treatment, especially with the incidence of storage time versus control. Guava fruits that received P_2 treatment recorded the lowest activity values during 14, 21 and 28 days of cold storage. On the contrary, fruits of control (P_1) treatment showed the highest values during all storage periods in the two seasons. Also, the application of both salicylic acid and citric acid were effective in reducing the activity of this enzyme. In this respect, the application of T_4 and T_5 were more effective since it showed the lowest enzyme activity during both seasons. With regarding interaction, it could be noticed that fruits subjected to hydro-cooling plus T_4 or T_5 treatments recorded the lowest enzyme activity in the first season. In the second one, the application of hydro-cooling plus T_5 treatment reached the lowest enzyme activity. However, control treatment showed the highest values in both seasons.

The results of the above-mentioned guava fruit characters were confirmed, since Pearson correlation coefficient data showed highly negative correlation between weight loss % and fruit firmness (-0.97^{**}), total chlorophyll (-0.98^{**}), vitamin C (-0.94^{**}) and acidity % (-0.98^{**}); and positive correlation with decay % (0.94^{**}), SSC% (0.98^{**}), PME activity (0.96^{**}) and total sugars % (0.97^{**}). Here we can point out that, reducing physiological weight loss% as a result of treatments might be reflected to maintain fruit firmness and retarding fruit decay and PME activity. These results could be explained according to the fact that hydro-cooling of fruit helps to remove field heat which reduces the rate of biochemical reactions lick respiration, transpiration and ethylene production rates **(Shiri *et al.*, 2013).** The retardation of different biochemical process is reflected to reduces the loss of fruit moisture consequently reduced weight loss, fruit freshness, delayed fruit senescence with raising the fruit resistance and maintains fruit firmness **(Bal and Celik, 2010).** Also, hydro-cooling retarded the hydrolysis of the starch and breakdown of insoluble propectin into soluble pectin **(Mattoo *et al.*, 1975).** Moreover, the application of salicylic acid (SA) encourage the accumulation of phenolic compounds, induce numerous defense genes and increase the activity of antioxidant enzymes that enhanced resistance of fruits against fungal attack **(Xu and Tian, 2008).** Also, SA applications retained the higher firmness after 6days of shelf life and reduced free radicals in bananas fruit **(Alali *et al.*, 2018).**

Table 4: Effect of hydro-cooling, and immersion in citric acid and salicylic acid on Pectin methylesterase activity (Unit/h/100g F.W.) of Guava fruit during cold storage at 10^{0}C and 90-95RH during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Pre-cooling treat.										
P_1:Control	0.69^{a}	0.88^{a}	1.04^{a}	1.16^{a}	**0.94^{A}**	0.84^{a}	0.97^{a}	1.11^{a}	1.10^{a}	**1.01^{A}**
P_2:Hydro-cooling	0.62^{a}	0.73^{b}	0.86^{b}	0.95^{b}	**0.79^{B}**	0.76^{a}	0.84^{a}	0.88^{b}	0.92^{b}	**0.85^{B}**
Dipping treat.										
T_1:Control	0.89^{a}	1.11^{a}	1.41^{a}	1.39^{a}	**1.20^{A}**	1.00^{a}	1.11^{a}	1.30^{a}	1.11^{a}	**1.13^{A}**
T_2:CA 2 mM	0.73^{b}	0.82^{b}	1.01^{b}	1.13^{b}	**0.93^{B}**	0.90^{ab}	1.01^{ab}	1.11^{b}	1.20^{a}	**1.06^{A}**
T_3:CA 4mM	0.62^{bc}	0.78^{bc}	0.85^{c}	1.07^{b}	**0.83^{BC}**	0.79^{bc}	0.91^{b}	0.93^{c}	0.97^{b}	**0.90^{B}**
T_4:SA 2 mM	0.54^{c}	0.66^{c}	0.76^{c}	0.87^{c}	**0.71^{C}**	0.71^{cd}	0.77^{c}	0.86^{cd}	0.90^{b}	**0.81^{BC}**
T_5:SA 4mM	0.50^{c}	0.65^{c}	0.73^{c}	0.82^{c}	**0.68^{C}**	0.62^{d}	0.72^{c}	0.78^{d}	0.85^{b}	**0.74^{C}**
Interaction										
P_1T_1	0.95^{a}	1.27^{a}	1.53^{a}	1.46^{a}	**1.30^{A}**	1.07^{a}	1.24^{a}	1.55^{a}	1.14^{b}	**1.25^{A}**
P_1T_2	0.77^{b}	0.92^{b}	1.18^{abc}	1.31^{b}	**1.05^{B}**	0.91^{bc}	1.06^{b}	1.19^{b}	1.34^{a}	**1.13^{B}**
P_1T_3	0.64^{cd}	0.83^{bc}	0.92^{bc}	1.29^{b}	**0.92^{C}**	0.86^{c}	0.98^{c}	1.08^{c}	1.11^{bc}	**1.01^{C}**
P_1T_4	0.58^{de}	0.70^{cd}	0.81^{bc}	0.93^{c}	**0.76^{D}**	0.73^{d}	0.81^{de}	0.92^{d}	0.97^{d}	**0.86^{D}**
P_1T_5	0.50^{e}	0.67^{cd}	0.75^{c}	0.83^{d}	**0.69^{EF}**	0.62^{e}	0.76^{ef}	0.83^{e}	0.92^{d}	**0.78^{E}**
P_2T_1	0.83^{b}	0.94^{b}	1.29^{ab}	1.32^{b}	**1.10^{B}**	0.93^{b}	0.98^{c}	1.05^{c}	1.08^{bc}	**1.01^{C}**
P_2T_2	0.68^{c}	0.72^{cd}	0.84^{bc}	0.95^{c}	**0.80^{D}**	0.88^{bc}	0.96^{c}	1.03^{c}	1.06^{c}	**0.98^{C}**
P_2T_3	0.60^{cd}	0.73^{cd}	0.78^{c}	0.85^{d}	**0.74^{DE}**	0.72^{d}	0.84^{d}	0.78^{ef}	0.83^{e}	**0.79^{E}**
P_2T_4	0.50^{e}	0.61^{d}	0.71^{c}	0.80^{d}	**0.66^{F}**	0.68^{d}	0.72^{fg}	0.79^{ef}	0.83^{e}	**0.76^{E}**
P_2T_5	0.50^{e}	0.63^{d}	0.70^{c}	0.81^{d}	**0.66^{F}**	0.61^{e}	0.68^{g}	0.73^{f}	0.78^{e}	**0.70^{F}**
Mean	**0.70^{B}**	**0.85^{AB}**	**1.00^{A}**	**1.15^{A}**		**0.80^{B}**	**0.95^{AB}**	**1.05^{A}**	**1.10^{A}**	
	Initial value= 0.46					Initial value= 0.53				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

***P_1**=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, **P_2**= (Hydro-cooling) Dipping in tap water at 2 ℃ for 10 mints , **T_1**=Control, **T_2**= Citric acid at 2mM, **T_3**= Citric acid at 4mM, **T_4**= Salicylic acid at 2mM and **T_5**= Salicylic acid at 4mM.*

This result is in agreement with the founding's of **Bons and Dhawan, (2006)** on guava, (**Kulkarni *et al*, (2004)** on mango fruits, **Kazemi *et al*. (2011)** on apple and **Zahra and Ahmad (2013)** on peach cv. 'Elberta'.

Vitamin C content

Data presented in Tables 5 indicate that, the use of hydro-cooling treatment (P_2) was better to maintaining vitamin C contents of guava fruits under cold storage, where it recorded the highest values of vitamin C contents throughout all storage periods as compared to control during the two seasons. Moreover, all dipping treatments were effective in maintaining this fruit quality attribute during cold storage versus control especially Salicylic acid solution at 4mM (T_5) treatment compared with the others in both seasons. The interaction between hydro-cooling and immersion treatments cleared an enhancement of vitamin C contents, especially the fruits that subjected to combination between hydro-cooling and Salicylic acid at 4mM (T_5) treatment which showed the highest values as compared with others during all storage periods (from 7 to 28 days), however, the fruits of control (P_1T_1) showed the lowest values. This trend was true in both seasons. This may be ascribed to the fact that vitamin C is a heat-sensitive substrate, so hydro-cooling treatment may inhibit the degradation of ascorbic acid. Also, citric acid and salicylic acid treatments play an important role in retarding fruit ripening process as lick respiration rate and prevent the free radical formation as well cell membrane disintegration that occurs by the reaction of lipoxigenase and lipid peroxidation, which minimizing the onset of fruit ripening with maintaining fruit quality **(Reddy and Sharma 2016).** These results are in line with the findings of **Trivedi and Desai (2006)** on guava and **Suriyan *et al*., (2017)** they summarized that, salicylic acid at 2.0mM as postharvest immersion treatment was effective in maintaining vitamin C content of 'Kimju' guava fruits.

Fruit color changes (Hunter L, a and b)

Data illustrated in figure 3 indicate that, generally the Hunter 'L' and 'b' values were increased with the incidence of storage time whereas the negative Hunter 'a' value was decreased. This trend was more pronounced with guava fruits of control as compared with that received hydro-cooling treatment. Guava fruits treated by citric acid (T_2 and T_3) and that received salicylic acid (T_4 and T_5) showed lower values Hunter 'L' and 'b' and higher value of Hunter 'a' as compared to control. The lowest Hunter 'L' and 'b'; and highest Hunter 'a' values were recorded with T_5 treatment in both seasons. The combination between hydro-cooling and postharvest immersion treatments was effective in reducing both Hunter 'L' and 'b' and increasing Hunter 'a' values. These results indicating progressive development of skin color of guava fruits of control (T_1) from green to yellow (Table 6) as compared to other treatments, where the improvement of yellowness (Hunter 'b') and skin lightness (Hunter 'L') values and loss of skin greenness (Hunter 'a') of guava fruits during cold storage were much earlier in guava fruits of control (T_1). The decrease in Hunter 'a' (greenness) which was accompanied with increasing in yellowness (Hunter 'b') values and loss of skin greenness of T_1 treatment during storage may be due to increases of the activities of chlorophyll degrading enzymes including chlorophyllase, chlorophyll oxidase and peroxidase **(Jain *et al*., 2001).** these results were in accordance with **Lo'ay and El Khateeb (2011)** they indicated that, postharvest application of salicylic acid delayed the ripening process of guava fruits through suppressed the respiration rate, reduced ethylene production and also delayed the onset of the respiratory climacteric during cold storage, however the control fruits showed a raped increase in respiration rate with a typical climacteric peak. The reducing of respiration rate in treated fruits may be ascribed to delaying the ripening process as showed by **Barman and Asrey (2014)** on mango and **Sahar and Wahab (2015)** on apricot. The results of guava fruit color character were confirmed, since Pearson correlation coefficient data showed highly negative correlation between fruit yellowness (Hunter 'b') color and fruit SSC (-.98**), SSC/acid ratio (-0.99**), pectin methylesterase (-0.98**) and total sugars (-0.96**); and highly positive correlation with vitamin C (0.97**) and acidity% (0.96**).

Table 5. Effect of Hydro-cooling, and immersion in citric acid and salicylic acid on vitamin C content (mg/100g F.W.) of Guava fruit during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Pre-cooling treat.										
P_1:Control	87.64^b	76.04^b	64.44^b	55.24^b	**70.84^B**	75.00^b	68.80^b	62.40^b	57.07^b	**65.82^B**
P_2:Hydro-cooling	92.98^a	78.98^a	68.78^a	61.38^a	**75.53^A**	83.30^a	76.47^a	70.20^a	65.47^a	**73.86^A**
Dipping treat.										
T_1:Control	81.60^e	64.60^e	51.60^e	42.10^e	**59.98^E**	71.30^d	62.08^e	55.36^e	50.19^d	**59.74^E**
T_2:CA 2 mM	85.50^d	72.00^d	61.00^d	48.00^d	**66.62^D**	73.46^d	66.24^d	59.76^d	56.68^c	**64.04^D**
T_3:CA 4mM	89.16^c	77.16^c	67.66^c	56.66^c	**72.66^C**	77.12^c	72.24^c	66.99^c	59.79^c	**69.03^C**
T_4:SA 2 mM	94.60^b	84.10^b	73.10^b	68.60^b	**80.10^B**	82.40^b	78.29^b	72.96^b	67.17^b	**75.21^B**
T_5:SA 4mM	100.70^a	89.70^a	79.70^a	76.20^a	**86.58^A**	91.49^a	84.33^a	76.45^a	72.55^a	**81.20^A**
Interaction										
P_1T_1	80.81^f	61.81^g	47.81^h	40.81^g	**57.81^G**	70.15^e	58.33^g	50.51^h	46.63^h	**56.41^I**
P_1T_2	82.24^f	72.24^e	60.24^f	45.24^f	**64.99^E**	70.23^e	63.58^f	58.76^g	53.25^g	**61.46^H**
P_1T_3	85.75^e	76.75^d	66.75^e	51.75^e	**70.25^D**	71.45^e	68.74^e	62.45^e	54.92^g	**64.39^G**
P_1T_4	90.57^{cd}	81.57^c	71.57^{cd}	66.57^c	**77.57^C**	77.54^d	73.82^d	67.59^d	62.75^e	**70.43^E**
P_1T_5	98.83^b	87.83^b	75.83^b	71.83^b	**83.58^B**	85.64^b	79.55^c	72.68^c	67.82^c	**76.42^C**
P_2T_1	82.39^f	67.39^f	55.39^g	43.39^{fg}	**62.14^F**	72.45^e	65.83^f	60.20^{fg}	53.74^g	**63.06^{GH}**
P_2T_2	88.75^d	71.75^e	61.75^f	50.75^e	**68.25^D**	76.69^d	68.89^e	60.75^{ef}	60.11^f	**66.61^F**
P_2T_3	92.57^c	77.57^d	68.57^{de}	61.57^d	**75.07^C**	82.78^c	75.74^d	71.52^c	64.65^d	**73.67^D**
P_2T_4	98.63^b	86.63^b	74.63^{bc}	70.63^b	**82.63^B**	87.25^b	82.76^b	78.33^b	71.58^b	**79.98^B**
P_2T_5	102.57^a	91.57^a	83.57^a	80.57^a	**89.57^A**	97.33^a	89.11^a	80.22^a	77.27^a	**85.98^A**
Mean	**81.26^A**	**77.51^B**	**66.61^C**	**58.31^D**		**71.40^A**	**72.64^A**	**66.30^B**	**61.27^C**	
	Initial value=106.16					Initial value= 102.85				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

***P_1**=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, **P_2**= (Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints , **T_1**=Control, **T_2**= Citric acid at 2mM, **T_3**= Citric acid at 4mM, **T_4**= Salicylic acid at 2mM and **T_5**= Salicylic acid at 4mM.*

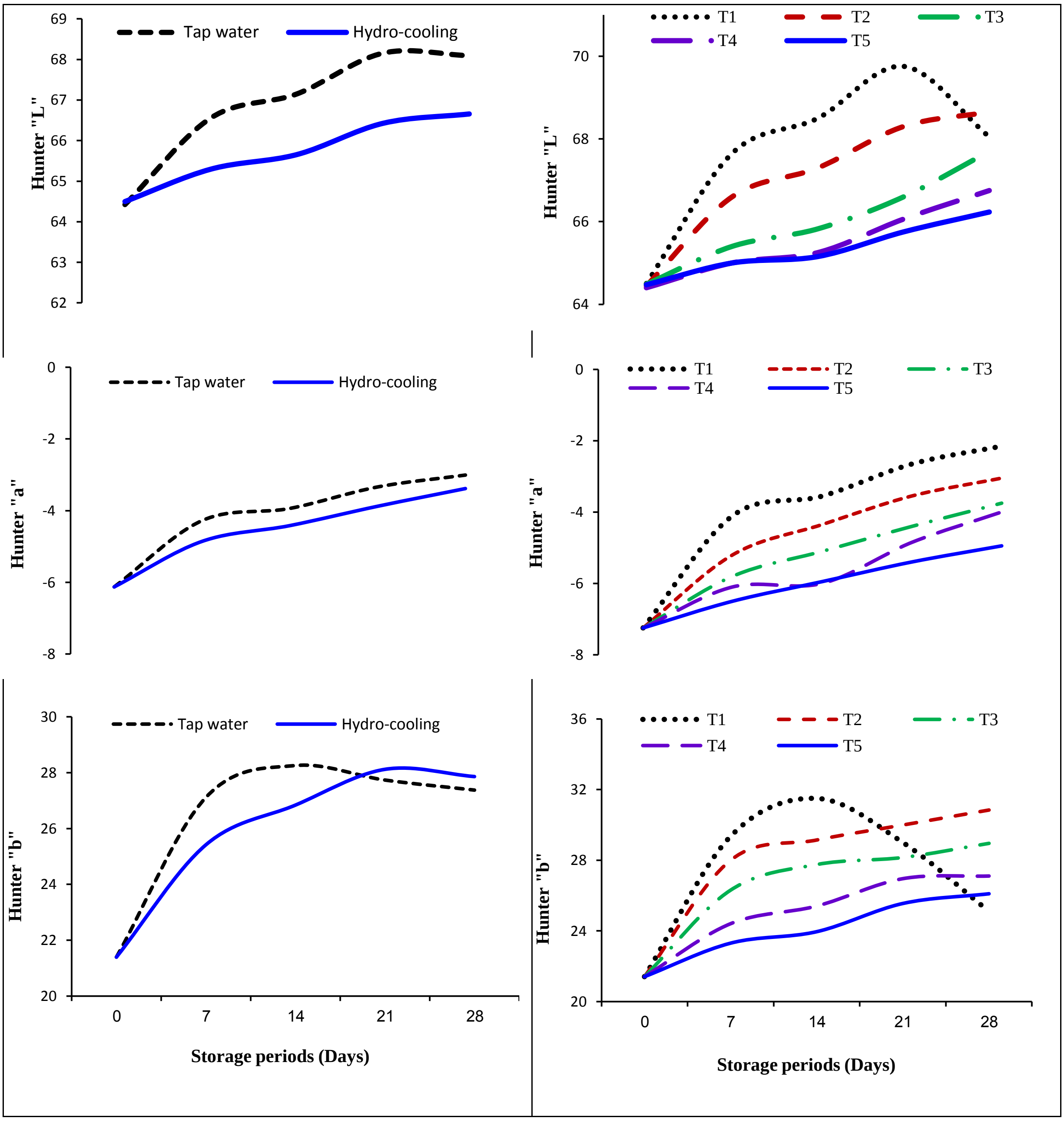


Figure 3. Effect of hydro-cooling and postharvest applications on average values of both seasons of guava fruits lightness (Hunter "L"), greenness (Hunter "b"), and yellowness (Hunter "a") during cold storage at 10°C and 90-95% RH.

P₁=*Dipping in tap water at room temperature at 25 ± 2ºC for 10mints,* ***P₂***= *(Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints ,* ***T₁***=*Control,* ***T₂***= *Citric acid at 2mM,* ***T₃***= *Citric acid at 4mM,* ***T₄***= *Salicylic acid at 2mM and* ***T₅***= *Salicylic acid at 4mM.*

Table 6. Effect of hydro-cooling, and immersion in citric acid and salicylic acid on guava fruits lightness (Hunter "L"), greenness (Hunter "b") and yellowness (Hunter "a") during cold storage at 10^{0}C and 90-95RH, in 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	**14**	**21**	**28**	**Mean**	**7**	**14**	**21**	**28**	**Mean**
Interaction	**Hunter "L"**									
P_1T_1	65.9^{a}	67.3^{a}	69.2^{a}	63.6^{cd}	**66.5^{A}**	68.7^{a}	69.6^{a}	71.2^{a}	68.1^{ab}	**69.4^{A}**
P_1T_2	65.2^{ab}	66.7^{ab}	67.5^{b}	66.0^{a}	**66.4^{A}**	67.6^{ab}	68.4^{ab}	69.8^{ab}	70.0^{a}	**69.0^{A}**
P_1T_3	64.4^{ab}	65.1^{bc}	66.2^{bc}	66.4^{a}	**65.5^{AB}**	66.0^{bc}	66.4^{bc}	67.2^{bc}	68.6^{ab}	**67.0^{BC}**
P_1T_4	63.9^{ab}	64.5^{cd}	65.3^{cd}	66.1^{a}	**65.0^{AB}**	65.4^{bc}	65.7^{bc}	66.4^{c}	67.3^{ab}	**66.2^{BC}**
P_1T_5	63.1^{ab}	63.9^{cd}	64.1^{d}	63.3^{d}	**63.6^{B}**	65.1^{bc}	65.7^{bc}	66.2^{c}	66.5^{b}	**65.9^{BC}**
P_2T_1	63.5^{ab}	65.3^{bc}	66.2^{bc}	65.1^{abc}	**65.1^{AB}**	66.6^{abc}	67.4^{abc}	68.3^{abc}	67.0^{b}	**67.3^{B}**
P_2T_2	62.3^{b}	64.6^{cd}	64.9^{cd}	66.0^{a}	**64.4^{AB}**	65.6^{bc}	66.2^{bc}	66.8^{bc}	67.3^{ab}	**66.5^{BC}**
P_2T_3	62.5^{b}	64.0^{cd}	64.9^{cd}	65.5^{ab}	**64.2^{AB}**	64.8^{c}	65.3^{bc}	66.0^{c}	66.8^{b}	**65.7^{BC}**
P_2T_4	63.2^{ab}	63.9^{cd}	64.3^{d}	65.1^{abc}	**64.1^{AB}**	64.6^{c}	64.8^{c}	65.7^{c}	66.2^{b}	**65.3^{C}**
P_2T_5	62.2^{b}	63.0^{d}	63.6^{d}	64.0^{bcd}	**63.2^{B}**	64.9^{c}	64.6^{c}	65.4^{c}	66.0^{b}	**65.2^{C}**
Mean	**65.9^{B}**	**66.4^{B}**	**67.3^{A}**	**67.4^{A}**		**63.6^{C}**	**64.8^{B}**	**65.6^{A}**	**65.1^{A}**	
	Initial value= 61.6					Initial value= 64.5				
Interaction	**Hunter "a"**									
P_1T_1	-3.2^{a}	-2.8^{a}	-2.5^{a}	-2.1^{a}	**-2.7^{A}**	-4.0^{a}	-3.4^{a}	-2.3^{a}	-2.0^{a}	**-2.9^{A}**
P_1T_2	-4.0^{c}	-3.9^{c}	-2.8^{b}	-2.6^{b}	**-3.3^{B}**	-5.2^{b}	-4.7^{d}	-3.3^{c}	-2.7^{c}	**-4.0^{C}**
P_1T_3	-4.2^{c}	-3.7^{c}	-3.2^{c}	-2.9^{c}	**-3.5^{B}**	-5.5^{c}	-4.9^{d}	-4.0^{de}	-3.4^{d}	**-4.5^{D}**
P_1T_4	-4.9^{de}	-4.5^{d}	-3.8^{d}	-3.2^{d}	**-4.1^{D}**	-5.7^{c}	-5.2^{e}	-4.2^{e}	-3.6^{d}	**-4.7^{D}**
P_1T_5	-5.1^{ef}	-4.8^{e}	-4.4^{e}	-4.3^{g}	**-4.7^{E}**	-6.3^{de}	-5.6^{f}	-5.1^{g}	-4.6^{f}	**-5.4^{F}**
P_2T_1	-3.7^{b}	-3.1^{b}	-2.8^{b}	-1.9^{a}	**-2.9^{A}**	-4.2^{a}	-3.7^{b}	-3.0^{b}	-2.3^{b}	**-3.3^{B}**
P_2T_2	-4.7^{d}	-4.3^{d}	-3.3^{c}	-2.8^{bc}	**-3.8^{C}**	-5.2^{b}	-4.0^{c}	-3.8^{d}	-3.4^{d}	**-4.1^{C}**
P_2T_3	-5.0^{e}	-4.5^{d}	-4.2^{e}	-3.5^{e}	**-4.3^{D}**	-6.1^{d}	-5.3^{e}	-4.8^{f}	-4.1^{e}	**-5.1^{E}**
P_2T_4	-5.3^{f}	-5.0^{ef}	-4.2^{e}	-4.0^{f}	**-4.6^{E}**	-6.5^{ef}	-6.8^{h}	-5.5^{h}	-4.4^{f}	**-5.8^{G}**
P_2T_5	-5.6^{g}	-5.2^{f}	-4.9^{f}	-4.9^{h}	**-5.1^{F}**	-6.7^{f}	-6.3^{g}	-5.7^{h}	-5.3^{g}	**-6.0^{G}**
Mean	**-5.5^{D}**	**-5.0^{C}**	**-4.2^{B}**	**-3.6^{A}**		**-4.6^{B}**	**-4.2^{B}**	**-3.6^{A}**	**-3.2^{A}**	
	Initial value= -6.13					Initial value= -7.25				
Interaction	**Hunter "b"**									
P_1T_1	30.2^{a}	32.5^{a}	25.6^{de}	20.1^{f}	**27.1^{BC}**	32.3^{a}	33.9^{a}	32.3^{ab}	30.3^{b}	**32.2^{AB}**
P_1T_2	28.5^{ab}	29.2^{b}	30.2^{b}	31.2^{a}	**29.8^{A}**	31.8^{ab}	32.9^{ab}	33.7^{a}	34.2^{a}	**33.2^{A}**
P_1T_3	27.4^{b}	28.7^{b}	29.0^{bc}	30.1^{ab}	**28.8^{AB}**	31.4^{ab}	32.5^{ab}	33.7^{a}	34.0^{a}	**32.9^{AB}**
P_1T_4	25.3^{c}	26.1^{cd}	27.4^{cd}	28.2^{bc}	**26.8^{BC}**	29.6^{c}	30.7^{cd}	31.3^{bc}	33.4^{a}	**31.3^{BC}**
P_1T_5	24.2^{cd}	24.8^{de}	26.5^{de}	27.3^{cd}	**25.7^{CD}**	28.3^{d}	28.9^{e}	30.3^{c}	32.4^{ab}	**30.0^{CD}**
P_2T_1	28.5^{ab}	30.5^{b}	32.4^{a}	30.1^{ab}	**30.4^{A}**	31.7^{ab}	33.6^{a}	32.8^{ab}	31.6^{ab}	**32.4^{AB}**
P_2T_2	27.5^{b}	29.1^{b}	29.8^{b}	30.5^{a}	**29.2^{A}**	30.5^{bc}	32.4^{ab}	32.8^{ab}	33.9^{a}	**32.4^{AB}**
P_2T_3	25.2^{c}	26.8^{c}	27.3^{cd}	27.8^{cd}	**26.8^{BC}**	30.0^{c}	31.3^{bc}	32.2^{ab}	33.3^{a}	**31.7^{AB}**
P_2T_4	23.5^{cd}	24.7^{de}	26.5^{de}	26.0^{de}	**25.2^{CD}**	28.2^{d}	29.5^{de}	30.2^{c}	32.0^{ab}	**30.0^{CD}**
P_2T_5	22.4^{d}	23.1^{e}	24.6^{e}	24.9^{e}	**23.8^{D}**	27.7^{d}	28.2^{e}	29.8^{c}	30.4^{b}	**29.0^{D}**
Mean	**30.2^{C}**	**31.4^{B}**	**31.9^{B}**	**32.6^{A}**		**26.3^{B}**	**27.6^{A}**	**27.9^{A}**	**27.6^{A}**	
	Initial value= 21.4					Initial value= 27.3				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

P_1*=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, *P_2*= (Hydro-cooling) Dipping in tap water at 2 ºC for 10 mints , *T_1*=Control, *T_2*= Citric acid at 2mM, *T_3*= Citric acid at 4mM, *T_4*= Salicylic acid at 2mM and *T_5*= Salicylic acid at 4mM.

Total sugars of fruits

Data in Table 7 show that, total sugars of guava fruits was reduced by the use of hydro-cooling treatment (P_2) as compared with control (P_1) throughout all cold storage periods (7, 14, 21 and 28) and seasons. Moreover, guava fruits that treated by both citric acid (T_2 and T_3) and salicylic acid (T_4 and T_5) showed a reducing effect on total sugars during cold storage in both seasons. the application of T_4 and T_5 treatments showed the lowest values of total sugars after 7 days of cold storage however, T_5treatments recorded the lowest values during other storage times (14,21 and 28 days) as compared with others and control (T_1) in the first season. By the second season, both T_4 and T_5 treatments recorded the lowest values during all storage periods. However, the fruits of control (T_1) showed the highest percentages of total sugars in both seasons. The interaction between hydro-cooling and dipping treatments cleared a reduction effect on the total sugar percent of fruits. Guava fruits that subjected to hydro-cooling plus salicylic acid at both concentrations (P_2T_4 and P_2T_5) recorded the lowest values of total sugar however, control fruits (T_1) and T_2 showed the highest values in most cases during both seasons.

Juice SSC%

Data of Table 7 clear that, guava fruits that subjected to postharvest hydro-cooling (P_2) treatment showed a reduction of accumulation of SSC% versus control (P_1). The fruits that treated byT_4 and T_5 recorded the significant lowest percent after 7 days of cold storage in the first season; however, the application of T_5 showed the lowest values after 14, 21 and 28 in the same season as well as all storage periods in the second one. Whereas, guava fruits of control (T_1) showed the highest values during the two seasons. Regarding interaction effects, the same Table (9) indicated that, the combination between postharvest hydro-cooling technique and dipping substances (P_2T_1, P_2T_2, P_2T_3, P_2T_4 and P_2T_5) treatments were more effective than tap water at room temperature plus immersion substances (P_1T_1, P_1T_2, P_1T_3, P_1T_4 and P_1T_5). Guava fruits received P_1T_5 treatment showed the lowest SSC percentages in all storage periods and seasons. However, fruits of control (P_1T_1) recorded the highest values during the two seasons.

Titratable acidity

The titratable acidity of guava fruit juice was affected by the use of hydro-cooling application as compared to tap water at room temperature (Table 8). Where, hydro-cooling application (P_2) maintained juice acidity at high percent versus control (P_1) till 28 days of cold storage in both seasons of the study. Also, postharvest applications of salicylic acid and citric acid showed a decrease in juice acidity as compared to control (T_1) during all storage periods in both seasons. The application of T_5 treatment was more effective, where it recorded the highest values during all storage periods in both seasons. The combinations between hydro-cooling and salicylic acid as well as citric acid treatments helped to maintain fruit acidity as compared to control. In this respect, guava fruits subjected to P_2T_5 recorded the highest values of juice acid; however, fruits of control (P_1T_1) showed the lowest values during all storage periods. This trend was recorded during both seasons.

SSC/acid ratio

Data illustrated in Table 8 clear that, guava fruits that subjected to hydro-cooling (P_2) treatment showed the lowest SSC/acid ratio as compared to control (P_1) in all cold storage periods in both seasons. Moreover, the use of dipping (T_2, T_3, T_4 and T_5) treatments was effective in reducing SSC/acid ratio as compared to control (T_1) during cold times. Guava fruits treated by T_5 showed the lowest SSC/acid ratio as compared to others; however, control treatment (T_1) showed the highest values. This trend was true during both seasons. The combination of hydro-cooling and salicylic acid as well as citric acid treatments helped to reduce the SSC/ acid ratio during cold storage. The application of P_2T_5 cleared the lowest values; however, control (P_1T_1) recorded the highest ratio. This trend was shown in all storage periods and both seasons. The reduction of total sugars of hydro-cooled and salicylic immersed fruits during cold storage may due to hydro-cooling immediately after the harvest alleviates field heat of guava fruits that restricted respiratory activities and inhibited water loss hence slow down the release of sugar during starch hydrolysis and liberating reducing sugars **(Abdel-salam and Ismail, 2017).** Also, these treatments delayed fruit ripening and senescence through stimulating the accumulation of active compounds and antioxidant enzymes such as catalase, peroxidase and superoxide dismutase which reduced free radical levels, lipid peroxidation, retarding fruit softening and inhibiting ethylene biosynthesis (**Huang *et al*., 2007**). This explains the decrease in SSC% and maintains the higher values of titratable acidity under cold storage **(Azzu, 2016).** However, these presses may be faster in control fruits. These results are in agreement with those of **Awad (2006)**, **Makwana *et al.* (2014)** on mango and **Alali *et al.* (2018)** on bananas cv. 'Grand Nain'.

Table 7. Effect of Hydro-cooling, and immersion in citric acid and salicylic acid on total sugars % and SSC % of Guava fruit during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days) 7	14	21	28	*Mean*	2018 Cold storage periods (days) 7	14	21	28	*Mean*
Pre-cooling treat.					**Total sugars %**					
P$_1$:Control	4.64^{a}	5.27^{a}	5.67^{a}	5.68^{a}	**5.32^{a}**	4.16^{a}	4.80^{a}	5.29^{a}	5.49^{a}	**4.94^{a}**
P$_2$:Hydro-cooling	3.83^{b}	4.16^{b}	4.64^{b}	4.87^{b}	**4.37^{b}**	3.14^{b}	3.61^{b}	4.14^{b}	4.45^{b}	**3.84^{b}**
Dipping treat.										
T$_1$:Control	5.16^{a}	5.77^{a}	6.17^{a}	5.38^{b}	**5.62^{a}**	4.53^{a}	5.18^{a}	5.82^{a}	5.83^{a}	**5.34^{a}**
T$_2$:CA 2 mM	4.71^{b}	5.28^{b}	5.62^{b}	5.95^{a}	**5.39^{a}**	4.10^{ab}	4.66^{b}	5.26^{b}	5.57^{a}	**4.90^{b}**
T$_3$:CA 4mM	4.27^{b}	4.66^{c}	5.12^{c}	5.45^{b}	**4.87^{b}**	3.70^{b}	4.21^{c}	4.62^{c}	4.92^{b}	**4.36^{c}**
T$_4$:SA 2 mM	3.73^{c}	4.16^{d}	4.75^{c}	5.19^{b}	**4.46^{b}**	3.06^{c}	3.58^{d}	3.97^{d}	4.37^{c}	**3.74^{d}**
T$_5$:SA 4mM	3.32^{c}	3.71^{e}	4.14^{d}	4.40^{c}	**3.89^{c}**	2.87^{c}	3.42^{d}	3.91^{d}	4.18^{c}	**3.59^{d}**
Interaction										
P$_1$T$_1$	5.72^{a}	6.53^{a}	6.83^{a}	5.11^{de}	**6.05^{a}**	4.84^{a}	5.84^{a}	6.40^{a}	6.15^{a}	**5.81^{a}**
P$_1$T$_2$	5.10^{ab}	5.82^{b}	6.20^{b}	6.64^{a}	**6.94^{a}**	4.60^{a}	5.31^{b}	6.12^{a}	6.30^{a}	**5.58^{a}**
P$_1$T$_3$	4.73^{b}	5.20^{c}	5.61^{c}	6.10^{b}	**5.41^{b}**	4.25^{b}	4.70^{c}	5.00^{b}	5.43^{b}	**4.85^{b}**
P$_1$T$_4$	4.22^{bc}	4.81^{cd}	5.40^{c}	5.93^{b}	**5.09^{bc}**	3.60^{c}	4.05^{d}	4.44^{c}	4.80^{c}	**4.22^{c}**
P$_1$T$_5$	3.44^{d}	4.00^{d}	4.33^{ef}	4.60^{ef}	**4.09^{de}**	3.53^{c}	4.10^{d}	4.50^{c}	4.76^{bc}	**4.22^{c}**
P$_2$T$_1$	4.60^{b}	5.00^{c}	5.50^{c}	5.64^{c}	**5.19^{b}**	4.22^{b}	4.52^{c}	5.23^{b}	5.50^{b}	**4.87^{b}**
P$_2$T$_2$	4.32^{bc}	4.74^{cd}	5.04^{d}	5.26^{d}	**4.84^{c}**	3.60^{c}	4.00^{d}	4.40^{c}	4.84^{c}	**4.21^{c}**
P$_2$T$_3$	3.81^{c}	4.12^{d}	4.62^{e}	4.80^{e}	**4.34^{d}**	3.14^{d}	3.71^{e}	4.24^{c}	4.40^{d}	**3.87^{c}**
P$_2$T$_4$	3.23^{e}	3.50^{e}	4.10^{g}	4.45^{ef}	**3.82^{f}**	2.52^{e}	3.10^{f}	3.50^{d}	3.93^{e}	**3.26^{d}**
P$_2$T$_5$	3.20^{e}	3.42^{e}	3.94^{g}	4.20^{f}	**3.69^{f}**	2.20^{e}	2.73^{g}	3.32^{d}	3.60^{e}	**2.96^{d}**
Mean	**4.50^{C}**	**5.15^{B}**	**5.55^{A}**	**5.70^{A}**		**4.05^{C}**	**4.65^{B}**	**5.15^{AB}**	**5.40^{A}**	
	Initial value=2.21					Initial value=2.08				
Pre-cooling treat.					**SSC %**					
P$_1$:Control	5.8^{a}	7.4^{a}	8.8^{a}	9.7^{a}	**7.9^{a}**	4.9^{a}	6.4^{a}	7.7^{a}	8.5^{a}	**6.9^{a}**
P$_2$:Hydro-cooling	5.4^{b}	6.8^{b}	7.6^{b}	8.3^{b}	**7.0^{b}**	4.1^{b}	5.7^{b}	6.6^{b}	7.7^{b}	**6.0^{b}**
Dipping treat.										
T$_1$:Control	6.7^{a}	8. 5^{a}	9.6^{a}	10.1^{a}	**8.8^{a}**	5.4^{a}	7.2^{a}	8.0^{a}	5.8^{a}	**7.5^{a}**
T$_2$:CA 2 mM	5.9^{b}	7.6^{b}	8.6^{b}	9.2^{b}	**7.8^{b}**	5.2^{a}	6.6^{b}	7.3^{b}	5.5^{ab}	**6.9^{b}**
T$_3$:CA 4mM	5.7^{b}	7.4^{b}	8.0^{c}	9.0^{b}	**7.5^{b}**	4.3^{b}	6.2^{b}	7.2^{b}	5.1^{bc}	**6.5^{b}**
T$_4$:SA 2 mM	5.1^{c}	6.6^{c}	7.7^{c}	8.7^{b}	**7.0^{c}**	4.0^{b}	5.6^{c}	7.1^{b}	4.9^{c}	**6.0^{c}**
T$_5$:SA 4mM	4.7^{c}	4.7^{d}	7.1^{d}	8.1^{c}	**6.4^{d}**	3.8^{b}	4.7^{d}	6.4^{c}	4.4^{d}	**5.4^{d}**
Interaction										
P$_1$T$_1$	6.6^{a}	8.9^{a}	10.0^{a}	10.7^{a}	**9.1^{a}**	6.0^{a}	7.7^{a}	8.7^{a}	9.8^{a}	**8.1^{a}**
P$_1$T$_2$	6.2^{b}	7.8^{b}	9.2^{b}	9.7^{b}	**8.2^{bc}**	5.4^{b}	6.9^{b}	7.6^{c}	8.6^{d}	**7.1^{b}**
P$_1$T$_3$	5.8^{c}	7.7^{bc}	8.3^{c}	9.7^{b}	**7.9^{cd}**	4.7^{d}	6.7^{b}	7.8^{b}	8.8^{c}	**7.0^{b}**
P$_1$T$_4$	5.7^{c}	6.9^{d}	8.3^{c}	9.3^{cd}	**7.6^{de}**	4.3^{e}	5.8^{d}	7.4^{c}	7.8^{ef}	**6.3^{d}**
P$_1$T$_5$	4.7^{d}	5.9^{e}	8.1^{c}	9.0^{d}	**6.9^{g}**	4.3^{e}	5.0^{f}	7.0^{d}	7.6^{g}	**6.0^{e}**
P$_2$T$_1$	6.7^{a}	8.0^{b}	9.2^{b}	9.5^{bc}	**8.4^{b}**	4.7^{d}	6.7^{b}	7.3^{c}	9.1^{b}	**7.0^{b}**
P$_2$T$_2$	5.6^{c}	7.4^{c}	8.0^{cd}	8.6^{e}	**7.4^{ef}**	5.0^{c}	6.3^{c}	7.0^{d}	8.0^{e}	**6.6^{c}**
P$_2$T$_3$	5.5^{c}	7.0^{d}	7.7^{d}	8.3^{ef}	**7.1^{fg}**	4.0^{f}	5.7^{d}	6.5^{e}	7.7^{fg}	**6.0^{e}**
P$_2$T$_4$	4.5^{d}	6.2^{e}	7.0^{e}	8.0^{f}	**6.4^{h}**	3.6^{g}	5.3^{e}	6.7^{e}	7.2^{h}	**5.7^{f}**
P$_2$T$_5$	4.7^{d}	5.4^{f}	6.1^{f}	7.1^{g}	**5.8^{i}**	3.3^{h}	4.3^{g}	5.7^{f}	6.3^{i}	**4.9^{g}**
Mean	**4.65^{D}**	**7.10^{C}**	**8.20^{B}**	**9.00^{A}**		**3.70^{D}**	**6.05^{C}**	**7.15^{B}**	**8.10^{A}**	
	Initial value= 3.8					Initial value=3.1				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

***P$_1$**=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, **P$_2$**= (Hydro-cooling) Dipping in tap water at 2 ℃ for 10 mints , **T$_1$**=Control, **T$_2$**= Citric acid at 2mM, **T$_3$**= Citric acid at 4mM, **T$_4$**= Salicylic acid at 2mM and **T$_5$**= Salicylic acid at 4mM.*

Table 8. Effect of hydro-cooling, and immersion in citric acid and salicylic acid on acidity% and SSC/ acid ratio of Guava fruit during cold storage at 10^{0}C and 90-95RH, during 2017 and 2018 seasons

Treatments	2017 Cold storage periods (days)					2018 Cold storage periods (days)				
	7	14	21	28	*Mean*	7	14	21	28	*Mean*
Pre-cooling treat.					**Acidity%**					
P$_1$:Control	0.78^{b}	0.67^{b}	0.56^{a}	0.34^{b}	**0.59^{b}**	0.95^{b}	0.79^{b}	0.58^{b}	0.47^{b}	**0.70^{b}**
P$_2$:Hydro-cooling	0.96^{a}	0.80^{a}	0.61^{a}	0.50^{a}	**0.72^{a}**	1.07^{a}	0.89^{a}	0.69^{a}	0.60^{a}	**0.81^{a}**
Dipping treat.										
T$_1$:Control	0.75^{c}	0.58^{c}	0.46^{b}	0.33^{b}	**0.53^{b}**	0.90^{b}	0.70^{b}	0.49^{c}	0.42^{c}	**0.63^{c}**
T$_2$:CA 2 mM	0.80^{c}	0.68^{bc}	0.54^{ab}	0.39^{ab}	**0.60^{ab}**	0.95^{b}	0.79^{ab}	0.56^{c}	0.46^{bc}	**0.69^{bc}**
T$_3$:CA 4mM	0.85^{bc}	0.73^{b}	0.63^{a}	0.41^{ab}	**0.65^{ab}**	1.00^{ab}	0.84^{ab}	0.60^{bc}	0.52^{bc}	**0.74^{bc}**
T$_4$:SA 2 mM	0.93^{ab}	0.80^{ab}	0.65^{a}	0.48^{ab}	**0.72^{ab}**	1.07^{ab}	0.90^{ab}	0.73^{ab}	0.59^{ab}	**0.82^{ab}**
T$_5$:SA 4mM	1.02^{a}	0.89^{a}	0.68^{a}	0.51^{a}	**0.78^{a}**	1.15^{a}	0.98^{a}	0.80^{a}	0.69^{a}	**0.91^{a}**
Interaction										
P_1T_1	0.70^{f}	0.55^{g}	0.41^{f}	0.27^{f}	**0.48^{f}**	0.82^{g}	0.68^{e}	0.43^{f}	0.38^{e}	**0.58^{f}**
P_1T_2	0.72^{ef}	0.61^{f}	0.52^{de}	0.34^{de}	**0.55^{e}**	0.90^{f}	0.72^{e}	0.50^{e}	0.40^{e}	**0.63^{e}**
P_1T_3	0.74^{ef}	0.66^{e}	0.61^{c}	0.32^{e}	**0.58^{e}**	0.95^{e}	0.76^{d}	0.53^{e}	0.44^{e}	**0.67^{e}**
P_1T_4	0.83^{d}	0.71^{d}	0.62^{c}	0.35^{de}	**0.63^{d}**	1.00^{d}	0.82^{c}	0.68^{c}	0.51^{cd}	**0.75^{d}**
P_1T_5	0.92^{c}	0.82^{c}	0.65^{bc}	0.43^{c}	**0.71^{c}**	1.10^{b}	0.96^{a}	0.75^{b}	0.62^{b}	**0.86^{b}**
P_2T_1	0.80^{de}	0.61^{f}	0.50^{e}	0.38^{d}	**0.57^{e}**	0.98^{de}	0.72^{e}	0.54^{e}	0.45^{de}	**0.67^{e}**
P_2T_2	0.88^{cd}	0.74^{d}	0.55^{d}	0.43^{c}	**0.65^{d}**	1.00^{d}	0.85^{c}	0.61^{d}	0.52^{c}	**0.75^{d}**
P_2T_3	0.95^{c}	0.80^{c}	0.64^{bc}	0.50^{b}	**0.72^{c}**	1.05^{c}	0.91^{b}	0.67^{c}	0.60^{b}	**0.81^{c}**
P_2T_4	1.03^{b}	0.89^{b}	0.67^{ab}	0.61^{a}	**0.80^{b}**	1.13^{b}	0.97^{a}	0.77^{b}	0.66^{b}	**0.88^{b}**
P_2T_5	1.12^{a}	0.96^{a}	0.71^{a}	0.59^{a}	**0.85^{a}**	1.20^{a}	1.00^{a}	0.84^{a}	0.75^{a}	**0.95^{a}**
Mean	**0.79^{A}**	**0.74^{A}**	**0.59^{B}**	**0.42^{B}**		**0.91^{A}**	**0.84^{AB}**	**0.64^{BC}**	**0.54^{C}**	
	Initial value=1.27					Initial value=1.33				
Pre-cooling treat.					**SSC/ acid ratio**					
P$_1$:Control	12.74^{a}	17.59^{a}	23.63^{a}	41.16^{a}	**23.78^{a}**	9.53^{a}	13.55^{a}	21.29^{a}	27.75^{a}	**18.03^{a}**
P$_2$:Hydro-cooling	10.06^{b}	14.02^{b}	19.43^{b}	25.58^{b}	**17.27^{b}**	7.66^{b}	11.11^{b}	16.01^{b}	20.48^{b}	**13.81^{b}**
Dipping treat.										
T$_1$:Control	14.26^{a}	21.56^{a}	30.27^{a}	44.99^{a}	**27.77^{a}**	10.54^{a}	16.03^{a}	25.23^{a}	32.71^{a}	**21.13^{a}**
T$_2$:CA 2 mM	12.54^{b}	17.37^{b}	23.60^{b}	34.80^{b}	**22.08^{b}**	9.72^{ab}	13.63^{b}	20.62^{b}	27.29^{b}	**17.82^{b}**
T$_3$:CA 4mM	11.62^{bc}	15.74^{b}	19.22^{c}	33.71^{b}	**20.07^{c}**	8.39^{bc}	12.37^{b}	18.97^{c}	24.30^{c}	**16.01^{c}**
T$_4$:SA 2 mM	9.97^{cd}	13.41^{c}	18.13^{c}	28.84^{c}	**17.59^{d}**	7.51^{c}	10.77^{c}	15.33^{d}	20.05^{d}	**13.42^{d}**
T$_5$:SA 4mM	8.61^{d}	10.93^{d}	16.42^{d}	24.52^{d}	**15.12^{e}**	6.81^{c}	8.84^{d}	13.11^{e}	16.22^{e}	**11.25^{e}**
Interaction										
P_1T_1	15.14^{a}	23.45^{a}	34.15^{a}	54.44^{a}	**31.80^{a}**	12.20^{a}	17.21^{a}	29.53^{a}	36.32^{a}	**23.81^{a}**
P_1T_2	14.17^{b}	19.34^{b}	25.38^{c}	40.29^{c}	**24.80^{b}**	10.44^{b}	15.14^{b}	23.20^{b}	31.50^{b}	**20.07^{b}**
P_1T_3	13.24^{c}	17.73^{c}	20.16^{e}	42.81^{b}	**23.49^{c}**	9.16^{c}	14.08^{c}	22.26^{c}	29.09^{c}	**18.65^{c}**
P_1T_4	11.69^{d}	15.35^{d}	19.84^{e}	38.00^{d}	**21.22^{d}**	8.30^{d}	11.95^{d}	16.76^{f}	23.14^{d}	**15.04^{d}**
P_1T_5	9.46^{f}	12.07^{f}	18.62^{f}	30.23^{f}	**17.59^{f}**	7.55^{e}	9.38^{f}	14.67^{h}	18.71^{f}	**12.57^{f}**
P_2T_1	13.38^{c}	19.67^{b}	26.40^{b}	35.53^{e}	**23.74^{c}**	8.88^{cd}	14.86^{b}	20.93^{d}	29.11^{c}	**18.44^{c}**
P_2T_2	10.91^{e}	15.41^{d}	21.82^{d}	29.30^{g}	**19.36^{e}**	9.00^{c}	12.12^{d}	18.03^{e}	23.08^{d}	**15.56^{d}**
P_2T_3	10.00^{f}	13.75^{e}	18.28^{f}	24.60^{h}	**16.66^{g}**	7.62^{e}	10.66^{e}	15.67^{g}	19.50^{e}	**13.36^{e}**
P_2T_4	8.25^{g}	11.46^{g}	16.42^{g}	19.67^{i}	**13.95^{h}**	6.73^{f}	9.59^{f}	13.90^{i}	16.97^{g}	**11.79^{g}**
P_2T_5	7.77^{g}	9.79^{h}	14.23^{h}	18.81^{j}	**12.65^{i}**	6.08^{g}	8.30^{g}	11.55^{j}	13.73^{h}	**9.92^{h}**
Mean	**11.4^{D}**	**15.81^{C}**	**21.53^{B}**	**33.37^{A}**		**8.60^{D}**	**12.33^{C}**	**18.65^{B}**	**24.115^{A}**	
	Initial value= 5.82					Initial value= 5.17				

Means followed by the same letters in a column under each category except mean row are not significantly different at level $P \leq 0.05$ according to DMRT.

***P$_1$**=Dipping in tap water at room temperature at 25 ± 2ºC for 10mints, **P$_2$**= (Hydro-cooling) Dipping in tap water at 2 ^{0}C for 10 mints , **T$_1$**=Control, **T$_2$**= Citric acid at 2mM, **T$_3$**= Citric acid at 4mM, **T$_4$**= Salicylic acid at 2mM and **T$_5$**= Salicylic acid at 4mM.*

Fruit shelf life

Shelf life in days at room temperature experiment was started directly after 28 days of cold storage.

Figure 4 show the enhancement effect of hydro-cooling as well as citric acid and salicylic acid (SA) treatments on extending the shelf life of guava fruits over control. Fruits treated with SA (T$_5$) in the first season as well as T_5 and T_6 in the second one showed the highest extending shelf life of guava fruits. The interaction between hydro-cooling and SA treatments was more effective in this respect as compared to control, especially T_4 and T_5 treatment in both seasons. This enhancement effect on the shelf life period might due to the role of both hydro-cooling and post-harvest dipping treatments that reduced physiological loss in weight, reduced rate of ripening, reduced rate of respiration, reduced spoilage, shelf-life and preserved quality in several fruits and vegetables; *viz.*,Cherry (**Manganaris *et al.*, 2007**), Tomato (**Shahi *et al.*, 2012**) and Plum (**Martinez *et al.*, 2003**). Moreover, SA increased phenolic compounds and enhanced resistant systems as previously shown in this study. These results are in line with those of **Tareen *et al.* (2012)** and **Amanullah *et al.* (2017)** who concluded that, exogenous applications of SA is a beneficial postharvest treatment to increase the shelf life of guava fruit during short term storage.

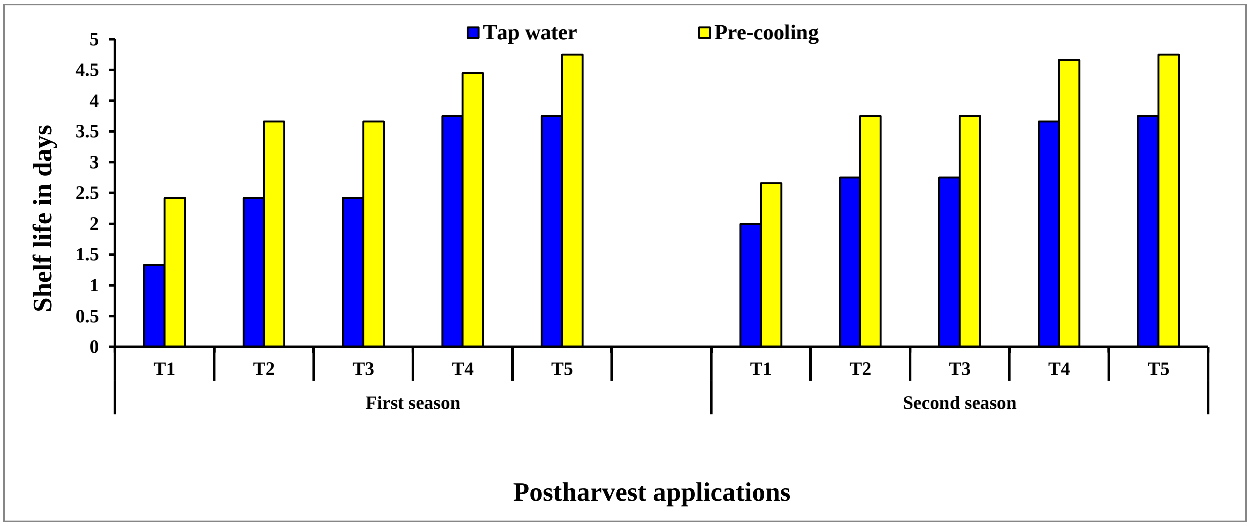


Figure 4. Effect of hydro-cooling, citric acid and salicylic acid on shelf life of guava fruits in days under room temperature after cold storage at 10^0C and 90-95RH. during 2017 and 2018 seasons
T_1=*Control,* ***T_2***= *Citric acid at 2mM,* ***T_3***= *Citric acid at 4mM,* ***T_4***= *Salicylic acid at 2mM and* ***T_5***= *Salicylic acid at 4mM.*

Conclusion

Postharvest treatment of guava fruits, especially hydro-cooling by using the hydro-cooling technique combined with immersion in salicylic acid at 4mM solution (SA) for 10 m could be used for preservation of guava fruits quality under cold storage at 10°C and 90-95% RH. This combination cleared a positive effect on fruit quality until 28 days of cold storage, where it maintained fruit quality attributes such as firmness, acidity as well as decreased decay incidence, ripening, SSC % and retarded fruit color changes compared with control. The present study demonstrates the efficacy and potential of both hydro-cooling and SA aqueous solution in extended Guava fruit shelf life after cold storage.

References

A.O.A.C., (2000). Official Methods of Analysis of International 17th edition. Gaithersburg, MD, USA, Association of Analytical Communities.

Abdel-salam, M. M. and F. A. Ismail, (2017). Abdel-salam, M. M. and F. A. Ismail, (2017). Effect of some Pre- and Postharvest Treatments on the Ability of "Balady" Orange Fruits to Storage. *Assiut Journal of Agricultural Sciences*, 48(4):154-167.

Aghdam M. S. M.; A. Motallebiazar, Y. Mostofi, J. F. Moghaddam, M. Ghasemneghad, (2010). Effect of Me SA vapor treatment on the postharvest quality of Hayward kiwi fruit. Acta Horticulturae, 877: 743-748.

Ahvenaien, R., (1996). New approaches in improving the shelf life of minimally processed fruits and vegetables .Trends in Food Science and Technology, 7(6):179-187.

Alali, A. A.; M. A. Awad, A. D. Al-Qurashi and S. A. Mohamed, (2018). Postharvest gum Arabic and salicylic acid dipping affect quality and biochemical changes of 'Grand Nain' bananas during shelf life. Scientia Horticulturae, 237:51-58.

Altunkaya, A. and V. Gokmen, (2008). Effect of various inhibitors on enzymatic browning, total phenol content and total antioxidant activity lettuce. Food Chemistry, 107: 1173-1179.

Amanullah, S.; M. Sajid, M. B. Qamar, S. Ahmad, (2017). Postharvest treatment of salicylic acid on guava to enhance the shelf life at ambient temperature. International Journal of Biosciences, 10 (3):92-106.

Anonymous, (2017). Ministry of agriculture and land reclamation, economic affairs sector, bulletin of the agricultural statistics.

Anthon, G. E. and D. M. Barrett, (2006). Characterization of the Temperature Activation of Pectin Methylesterase in Green Beans and Tomatoes. J. Agric. Food Chemistry, 54(1):204-211.

Asghari, M. and M. S. Aghdam, (2010). Impact of salicylic acid on post-harvest physiology of horticultural crops. Trends in Food. Sci. and Technol., 21(10):502-509.

Awad, R. U. A., (2006). Effect of some natural pre-harvest treatments on mineral content, yield, fruit quality and storability of mango fruits; Ph.D. Thesis, Fac. Agric., Alex. Univ.

Azzu, Y. M., (2016). Modulation of Fruit Ripening, Storage Time and Quality of Fruit with Emulsion of Chitosan Alone and Loaded with Salicylic Acid or Oxalic Acid. PhD. Thesis, Curtin University, Australia.

Baird, C. D., (1976). A numerical procedure for calculating heat transfer in bulk loads of fruits or vegetables. *ASHRAE Transactions*, 82, 525.

Bal E. and S. Celik, (2010). The effects of postharvest treatments of salicylic acid and potassium permanganate on the storage of kiwifruits. Bulg. J. Agric. Sci., 16(2):576-584.

Baladhiya, C. and J. Doshi, (2016). Precooling techniques and applications for fruits and vegetables. *International Journal of Processing and Post Harvest Technology*, 7(1):141-150

Barman, K. and R. Asrey, (2014). Salicylic acid pre-treatment alleviates chilling injury, preserves bioactive compounds and enhances shelf life of mango fruit during cold storage. *Journal of Scientific and Industrial Research* 73:713-18.

Bons, H. K. and S. S. Dhawan, (2006). Effect of heating/freezing with added chemical preservation on pulp preservation of guava (*Psidium guajava* L.). Haryana Journal of Horticultural Sciences, 35(1/2):22-25.

Boora, R. S., (2012). Improvement in guava (*Psidium guajava* L.) A review. *Agric. Rev*., 33(4):341-349.

Bousquet, J. F. and K. V. Thimmann, (1984). Lipid peroxidation from ethylene from1-aminocyclopropane-1 -carboxylic acid and may operate in leaf senescence. *Proceedings of the National Academy of Sciences* USA, 81(6):1724-1727.

Bron, I. U.; R.V. Ribeiro, F. C. Cavalini, A.P. Jacomino and M. J. Trevisan, (2005). Temperature related changes in respiration and Q_{10} coefficient of guava. *Scientia Agricola*., 62 (5):458-463.

Duncan, D. B., (1955). Multiple range and multiple F test. J. Biometrics, 11: 1-42.

Ennab, H. A.; M. A. El Shemy and S. M. Alam-Eldein, (2020). Salicylic acid and putrescine to reduce postharvest storage problems and maintain quality of murcott mandarin fruit. Agronomy, 10(1):1- 15.

Gordon, M. H., (1990). The mechanism of antioxidant action *in vitro*. In food Antioxidant, B. J. F. Hudson (Ed.), p.1-50.Elsevies Applied Science, London.

Huang, R.; R. Xia, L. Hu and M. Wang, (2007). Antioxidant activity and oxygen scavenging system in orange pulp during fruit ripening and maturation. *Scientia Horticulturae*, 113:166-172

Jain, N.; K. Dhawan, S. P. MalhotraSiddiqui and R. Singh, (2001). Compositional and enzymatic changes in guava (*Psidium guajava* L.) fruits during ripening. *Acta Physiol. Plant*., 23 (3):357-362.

Jain, N.; K. Dhawan, S. Malhotra and R. Singh, (2003). Biochemistry of fruit ripening in guava (*Psidium guajava* L.) compositional and enzymatic changes. *Plant Foods for Human Nutrition,* 58(4):309-315.

Jobling, B. J., (2001). Correct cool chain management is essential for all fruit and vegetables. *Sydney Postharvest Laboratory*, 1–4. http://www. postharvest. com.au/Shelflife.

Kazemi M.; M. Aran and S. Zamani, (2011). Effect of salicylic acid treatments on quality characteristics of apple fruits during storage. American Journal of Plant Physiology. 6(2):113-119.

Kulkarni, S. G.; V. B. Kudachikar, M. S. Vasantha, M. N. Prakash, B. Prasad, K. V. R. Ramana, (2004). Studies on effect of ethrel dip treatment on the ripening behavior of mango variety 'Neelum'. J. Food Sci Technol 41:216-220.

Lo'ay, A. A. and A. Y. El Khateeb, (2011) delaying guava riprning by exogenous salisylic acid J. Plant Production, Mansoura Univ., 2 (5):715-724

Makwana S. A.; N. D. Polara and R. R. Viradia, (2014). Effect of Pre-Cooling on Post Harvest Life of Mango (*Mangifera Indica* L.) CV. Kesar. Food Science and Technology 2(1):6-13.

Manganaris, G. A.; I. F. Ilias, M. Vasilakakis and I. Mignani, (2007). The effect of hydrocooling on ripening related quality attributes and cell wall physiochemical properties of sweet cherry fruit. *Internat. J. Refrigeration,* 30:1386-1392.

Martinez, R. D.; S. Castillo and D. Valero, (2003). Forced-air cooling applied before fruit handling to prevent mechanical damage of plums. *Post harvest-Biol. & Technol*., 28(1):135-142.

Mattoo, A. K.; T. Murata, E. B. Pantastico, K. Chachin and K. Phan, (1975). Chemical changes during ripening and senescence. In: PANTASTICO, Er. B. Postharvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. Westport: The AVI Publishing, pp.103-127

McGuire, R. G., (1992). Reporting of Objective Color Measurements. *HortScience*, 27(12):1254-1255.

Mercado-Silva, E.; P. B. Bautista and M. A. Garcia-Velasco, (1998). Fruit development, harvest index and ripening changes of guavas produced in Central Mexico. Postharvest Biology and Technology, 13, 143-150.

Mitra, S. K.; H. L. Devi, I. Chakraborty and P. K. Pathak, (2012). Recent development in post harvest physiology and storage of guava. Acta Hort., 959:89-95.

Netravati, J. S. L.; G. J. Suresha and G. S. K. Swamy, (2015). Influence of eco-friendly post harvest treatments on pulp chroma and hue on mango cv. Alphonso fruits. *The Bioscan*, 10(1):29-32.

Ranganna, S., (1997). Handbook of Analysis and Quality Control for Fruits and Vegetable Products. Tata McGraw Hill Publishing Co. Ltd., New Delhi, 875-886.

Reddy, V. Y. and R. R. Sharma, (2016). Effect of pre-harvest application of salicylic acid on the postharvest fruit quality of the Amrapali mango (Mangifera indica) Indian Journal of Agricultural Sciences, 86(6):727-731

Rudnucki, R. M.; J. Nowak and D. M. Goszczynska, (1991). Cold storage and transportation conditions for cut flowers cuttings and potted plants. *Acta Hort*., 298:225.

Sahar, M. and A. E. Wahab, (2015). Apricot Postharvest Fruit Quality, Storability and Marketing in Response to Pre harvest Application. *Middle East Journal of Agriculture Research*. 4: 347-358

Saxena, M. and C. P. Gandhi, (2014). Indian Horticulture Database, National Horticulture Board (NHB), Gurgaon. Department of Agriculture & Cooperation, Govt. of India. pp.76-83.

Shafiee, M.; T. S. Taghavi and M. Babalar, (2010). Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid, and calcium dipping) improved postharvest fruit quality of strawberry. Sci. Hortic., 124:40-45.

Shahi, N. C.; U. C. Lohani, K. Chand and S. Anupama, (2012). Effect of pre-cooling treatments on shelf-life of tomato in ambient condition. *Internat. J. Food, Agric. & Veteri. Sci*., 2(3):50-56.

Shiri, M. A.; M. Ghasemnezhad, D. Bakhshi and H. Sarikhani, (2013). Effect of postharvest Putrescine application and chitosan coating on maintaining quality of table grape cv. Shahroudi during longterm storage. Journal of Food Processing and Preservation 37(5):999-1007

Silip, J. J. and S. A. Hajar, (2007). Relationship Between Pre-cooling, Storage Temperature and Storage Duration To The Quality Characteristics Of Guava (Psidium Guajava L. cv. Kampuchea). 1st International Guava Symposium. Acta Hort., 735, 70

Snedecor, G.W. and W.G. Cochran, (1980). Statistical Methods 6th ed. The Iowa state, Univ. Press, Amer, Iowa, U.S.A.

Suriyan, S.; M. Boonwat, B. Panida, T. Chairat, T. Racha and Y. Pannipa, (2017). Salicylic acid immersion maintains physiochemical quality and enhances bioactive compounds in 'Kimju' guava fruit during cold storage. Emirates Journal of Food and Agriculture, 29(8):620-628

Tareen, M. J.; N. A. Abbasi, and I. A. Hafiz, (2012). Postharvest application of salicylic acid enhanced antioxidant enzyme activity and maintained quality of peach cv.'Flordaking' fruit during storage. *Scientia Horticulturae*, 142, 221-228.

Trivedi, Y. V. and M. M. Desai, (2006). Effect of different storage techniques and conditions on quality and shelf life of guava fruits. *Crop Prot. Prod.*, 2 (2):75-78.

Turk, R. and E. Celik, (1994). The effects of vacuum precooling on the half cooling period and quality characteristic of iceberg lettuce. *Acta Hort.* 368:825-829.

Wang, C.Y., (2010). Approaches to reduce chilling injury of fruits and vegetables. *Horticultural Reviews*, (1)15:63.

Watkins, C. and J. Harman, (1981). Use of penetrometer to measure flesh firmness of fruit. Orchardist N.Z. 54:14-16.

Xu, X. and S. Tian, (2008). Salicylic acid alleviated pathogen-induced oxidative stress in harvested sweet cherry fruit, Postharvest Biol. Technol., 49(3):379-385.

Zahra, K. and E. Ahmed, (2013). Postharvest application of salicylic acid improves storability of peach (*Prunus persica* cv. Elberta) fruits. Intl. J. Agri. Crop. Sci., 5(6):651-655.

تأثير التبريد المبدئي والغمس في حمض السالسيليك وحمض السيتريك على الجودة والقدرة التخزينية لثمار الجوافة

مها حسيب عبد العزيز

قسم بحوث تداول الفاكهة– معهد بحوث البساتين– مركز البحوث الزراعية– الجيزة – مصر

تعد ثمار الجوافة من الثمار الحساسة ولذا لا تتمتع بفترة عرض طويلة في الأسواق ولهذا كان من الضروري البحث عن تكنيك جديد يطيل من فترة العرض. وقد أجريت هذه الدراسة لتقيم الفوائد المحتملة من استخدام التبريد المبدئي بعد الحصاد وكذا الغمس في محلول حمض السيتريك وحمض السالسيليك على صفات الجودة لثمار الجوافة تحت ظروف التخزين المبرد. وقد استخدم لذلك ثمار جوافة مكتملة النمو (بداية اللون الأصفر) بعد الجمع مباشرة حيث أجريت معاملات الغمس في حمض السيتريك و حمض السالسيليك بتركيزي 2 و4 مللمول بالإضافة إلى معاملة المقارنة . هذه المعاملات تم تطبيقها مصحوبة بالتبريد المبدئي باستخدام الماء البارد على درجة 2مº لمدة 10 دقائق وكذلك باستخدام الماء على درجة حرارة الغرفة. الثمار المعاملة تم تخزينها على درجة 10مº ورطوبة نسبية تتراوح بين 90 إلى 95 % لمدة 28 يوم.

وقد أوضحت النتائج أن المعاملة المشتركة بين التبريد المبدئي وحمض السالسيليك بتركيز 4 مللمول أظهرت أقل قيم لكل من الفقد في وزن الثمار وتلف الثمار والسكريات الكلية والمواد الصلبة الذائبة بالعصير ونشاط إنزيم البكتين ميثايل استريز مقارنة بباقي المعاملات حتى 28 يوم من التخزين المبرد. علاوة على ذلك فان هذه المعاملة حافظت على أعلى صلابة للثمار والحموضة وفيتامين ج طوال فترات التخزين (7 و 14 و21 و28 يوم) كما زادت مدة عرض الثمار وذلك مقارنة بمعاملة المقارنة.

النتائج أوضحت انه يمكن استخدام تكنيك التبريد المبدئي مصحوبا بالغمس في حمض السالسيليك بتركيز 4 مللمول كمعاملة بعد الحصاد للحفاظ على جودة ثمار الجوافة أثناء التخزين المبرد وكذا إطالة فترة العرض بعد التخزين.